Supplementary Material

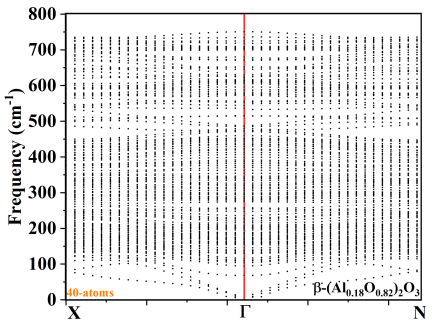

Figure 1: The full phonon dispersion for the 40-atom (120 phonon modes) supercell used to model the alloy disorder with 18% aluminum fraction

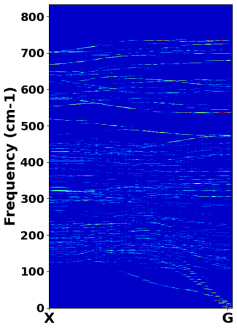

Figure 2: The effective phonon dispersion (30 phonon modes corresponding to 10atom primitive cell of GaO)in the $X-\Gamma$ direction with 18% aluminum fraction

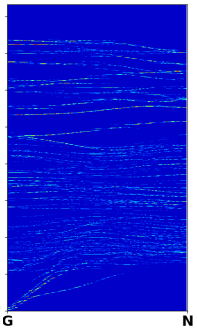

Figure 3: The effective phonon dispersion (30 phonon modes corresponding to 10atom primitive cell of GaO)in the $\Gamma-N$ direction with 18% aluminum fraction

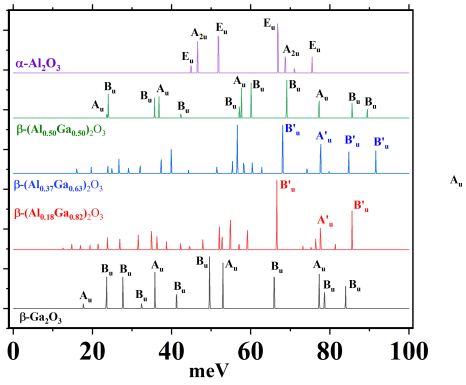

Figure 4: The comparison of the IR spectrum obtained for the alloy using the Brillouin zone unfolding scheme. Some of the modes that are labeled show a trend of moving to higher energies with increasing aluminum fraction in the AlGaO alloy

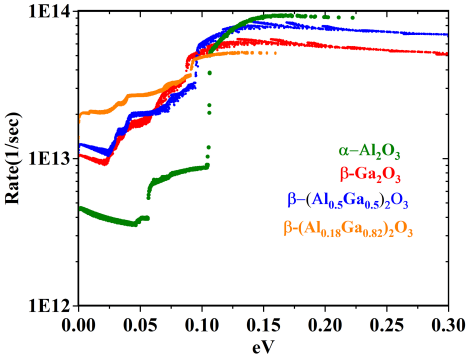

Figure 5: The polar optical phonon scattering rate for varying aluminum compositions calculated from first principles

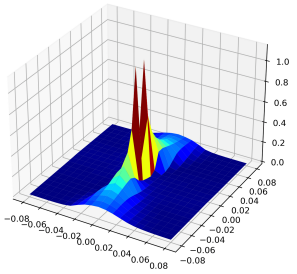

Figure 6: The polar electron-phonon interaction elements showing the $\frac{1}{|q|}$ dependence in $\beta-(Al_{0.18}Ga_{0.82})_2O_3$